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FOREST PEST MANAGEMENT

BIOLOGICAL EVALUATION
R2-95-01

EMERGENCE AND OVERWINTERING BROOD OF DOUGLAS-FIR BEETLE FIVE YEARS AFTER THE CLOVER MIST FIRE ON THE CLARKS FORK RANGER DISTRICT, SHOSHONE NATIONAL FOREST, WYOMING

United States Department of Agriculture

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Forest Pest Management
Denver, Colorado

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ABSTRACT

The emergence of adult Douglas-fir beetles (DFB), *Dendroctonus pseudotsugae* Hopkins, from caged brood trees in 1993, occurred from May to September, with a peak in mid- to late June. The 1993 emergence pattern is very similar to that observed in 1990 and 1992. In late fall 1993, live DFB adults were found under the bark of trees from which emergence was presumed to have been complete, because the trees had been attacked during summer of 1992. For the '92-'93 DFB generation, emerging adults were far fewer than overwintering brood, suggesting poor winter survival and/or a shift to a 2-year life cycle. Females comprised 65% of the emerging adults.

Overwintering brood densities of the '93-'94 DFB generation averaged 10.9 per 36 sq. in. bark sample in October 1993. Brood densities were 63% lower than 1992 levels, but similar to 1989 and 1991 levels. Atypical for DFB, most overwintering brood were in the larval stage. The number of gallery starts per sample was similar to those found in the three preceding years of epidemic DFB populations, suggesting adequate attack densities. About three DFB survived to fall 1993 per attacking adult in infested trees, portending increasing populations. However, portions of many samples were unoccupied, indicating less than full utilization of the food resource, and unsuccessfully attacked trees were noticeably abundant. Natural enemies were inconsistently and infrequently recovered.

The DFB population is expected to increase (up to threefold) from 1993 to 1994, assuming normal winter temperatures, based on conclusions from brood data. Management alternatives to reduce the impact of the DFB epidemic are discussed.

INTRODUCTION

This evaluation is the fifth in a series that chronicles extensive tree mortality caused by the Douglas-fir beetle (DFB), *Dendroctonus pseudotsugae* Hopkins (Coleoptera: Scolytidae), in the Cathedral Cliffs area of northwestern Wyoming (Pasek 1990, 1991; Pasek and Schaupp 1992; Schaupp 1993). Douglas-fir weakened by the Clover Mist Fire of 1988 provided the opportunity for resident DFB populations to increase; favorable conditions have allowed outbreak populations of DFB to persist in apparently healthy trees. A narrative summary follows.

The Clover Mist Fire burned onto the Clarks Fork Ranger District, generally south of U.S. Highway 212 and Wyoming Route 296 (Forest Route 100). In 1989, entomologists determined that large numbers of DFB were present in large diameter, blackened Douglas-fir trees (Pasek 1990). DFB brood production, measured in late fall of 1989 at the beginning of the overwintering period, was low to moderate. Most broods were in the callow adult stage, typical for this one-generation-per-year beetle.

By 1990, it appeared that an epidemic of DFB was developing in the area adjoining the fire boundary. Most, if not all, areas of large-diameter Douglas-fir adjacent to burned areas likely were infested by DFB in 1990 (Pasek 1991). Groups of DFB-killed trees also were evident in small pockets located at relatively short distances from the fire boundary, as well as on the upper east side of the Clarks Fork canyon, several miles distant. DFB were successfully attacking green, apparently healthy trees, as well as those scorched by fire. This movement of DFB from trees burned in 1988 into green trees also was documented elsewhere in the greater Yellowstone area (Amman and Ryan 1991).

Brood production increased dramatically in the '90-'91 DFB generation (Pasek 1991). The overwintering brood, consisting of about half immature and half callow adult stages, appeared healthy and few natural enemies were detected. A cursory examination of the brood in spring 1991 indicated very poor overwintering survival. The number of trees attacked in 1991 appeared to be similar to the number attacked in 1990.

Brood production decreased in the '91-'92 DFB generation to a lower density similar to that observed in 1989. Also similar to 1989 was the stage of overwintering brood, predominantly callow adults. Natural enemies of DFB were abundant, having built up on the persistent beetle population. DFB occupied green Douglas-fir only, because fire-scorched trees were no longer suitable or available. The number of trees killed by this DFB generation was about half as many as killed by the '90-'91 generation. A DFB population increase of 1.5 to 3 times was predicted for 1992.

Brood production increased in the '92-'93 DFB generation by about 3 times, returning to the high density level of the '90-'91 generation. Larvae comprised 79% of the overwintering brood, a greater percentage than noted in the '90-'91 generation. A population increase of 4-10 times was predicted for 1993, barring unusually high overwintering mortality.

The purposes of this evaluation were to predict the course of the DFB epidemic for 1994 and to document its progress while acquiring useful biological information on DFB. Activities included monitoring adult emergence from trees infested by the '92-'93 DFB generation, estimating overwintering population levels of the '93-'94 DFB generation, and examining stand and tree conditions at several sites on the Clarks Fork Ranger District.

METHODS

Wire-mesh screen cages (1' x 2') were attached to the north sides of 12 standing, heavily-infested Douglas-fir on 11-12 May 1993. Diameter at breast height (DBH) was recorded for each caged tree. Four trees per site were caged at three sites located near Camp Creek, Dead Man Creek, and the K-Z Ranch. Adult DFB that emerged under these cages were collected approximately weekly until 15 September 1993. Collected DFB

were stored in alcohol and transported to the Rapid City Service Center office, where they were counted and their sex determined.

Bark samples (6" x 6") were removed at a height of 5-7 feet from the north and the south sides of each of 16 Douglas-fir trees currently infested by DFB on 26-27 October 1993. Sample sites were located at the northeastern edge of the Cathedral Cliffs Sale area, near Dead Man Creek, at the Reef Creek Picnic Ground and on the eastern side of the Reef Creek drainage about 600 feet above the Picnic Ground. DBH was recorded for each sample tree. Live DFB and DFB natural enemies dislodged from the bark sample during removal were identified, counted, and discarded. Number of gallery starts also was counted. Bark samples were stored in plastic bags and transported to the Rapid City Service Center office, where they were examined. Total inches of egg gallery were measured for each bark sample. Phloem was shaved with a knife to locate all remaining live insects in each sample. Numbers of live DFB brood were tallied by life stage and DFB natural enemies counted. Means and standard deviations by sample site were calculated for all variables measured. Spearman's rank correlation, r_S , was used to assess association between select variable pairs. The variable r_S is a non-parametric, special case of Pearson's correlation coefficient which summarizes the standardized covariance of two variables as a value between +1 and -1.

Using the same methods, bark samples were removed from two caged trees per site on 26-27 October 1993, when wire-mesh emergence cages were taken down. One sample was taken from under the caged area and the other from the opposite side of the tree. Bark samples were handled and examined as above, except that no gallery measurements were taken.

RESULTS

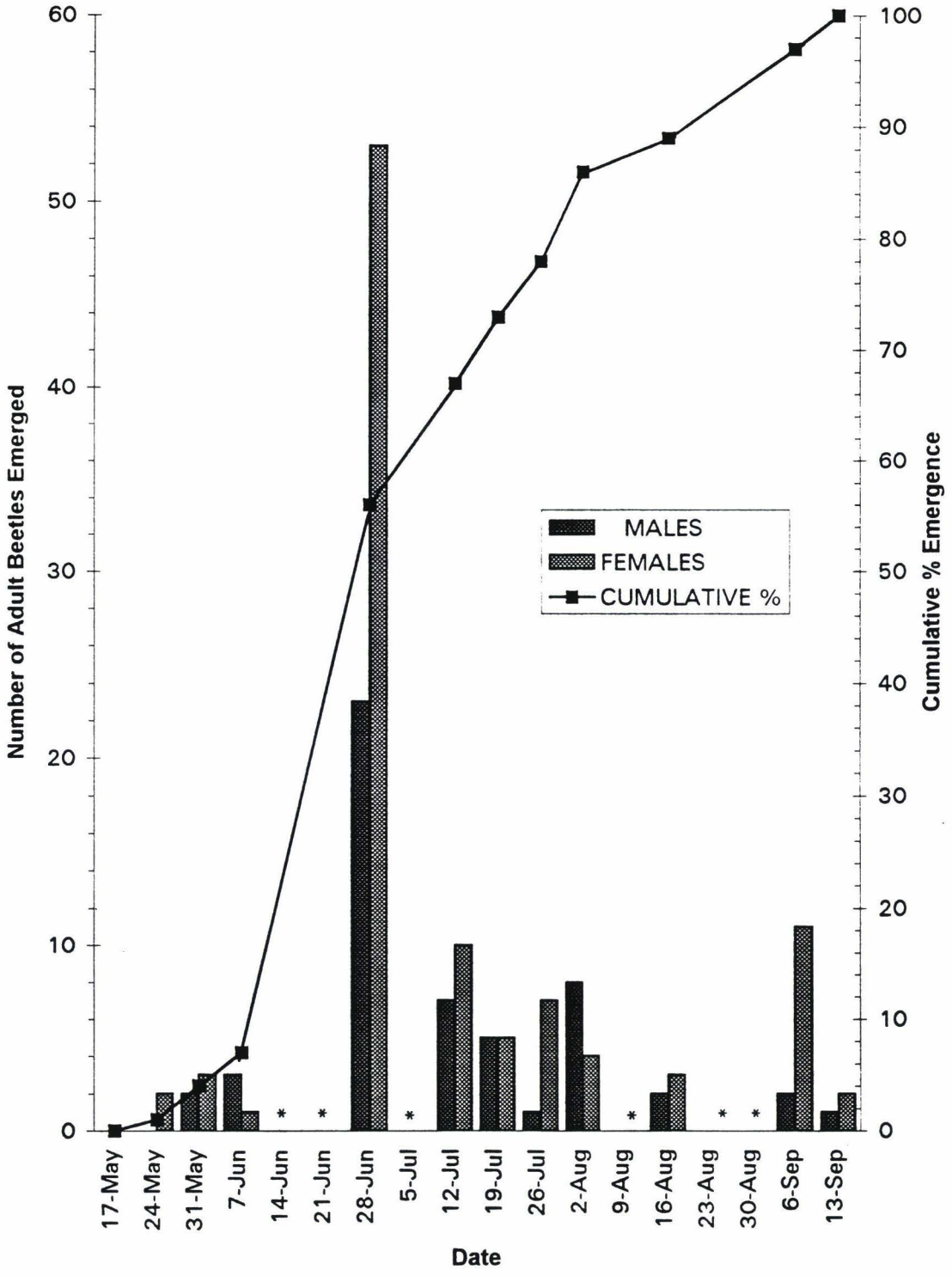
In 1993, adult DFB beetles emerged all summer from their brood trees. Most DFB emerged in June (Fig. 1). This pattern -- low-level, asynchronous emergence all summer punctuated by a June peak -- was evident at all three sites, despite the fact that collections could not be made every week. The Camp Creek site was unlike the other two in that low-level emergence occurred in August and September rather than during May, July, and August.

Relatively sparse DFB emergence was observed in 1993, with a total of 156 adult DFB collected from emergence cages. This averages out to 6.5 adult DFB per square foot of bark surface using total DFB collected per cage over the entire trapping period (standard deviation = 5.2, n = 12 cages). The range of total DFB collected per cage was 1-39 DFB adults or 0.5-19.5 DFB per square foot. There was no significant association between caged tree diameter and total beetle emergence per caged tree (r_S = 0.17, $p >> 0.05$, n = 12). By site, K-Z Ranch accounted for about half of all DFB collected (53%), while about equal numbers emerged at Dead Man Creek (22%) and Camp Creek (24%). Females comprised 65% of all DFB that emerged and outnumbered males in two-thirds of the collections (Fig. 1). There was no sex-specific pattern of emergence other than the preponderance of females.

Evidently, not all new adults from the '92-'93 generation emerged from their brood trees during 1993. In October 1993, four of six caged trees examined still contained live DFB adults under the bark. Expressed in terms of density, an average of 1.2 live DFB adults per square foot of bark surface (standard deviation = 1.6, n = 12 samples) was found in bark samples taken from these six trees. An average of 7.1 adult DFB per square foot of bark surface (standard deviation = 6.4) had been collected from these caged trees between May and September. Because bark samples were taken after emergence had ceased, the DFB found under the bark in October were about to spend their second winter within their host tree. An extended life cycle within the DFB population, with some individuals overwintering a second time, could affect overwintering survival and brood production in subsequent years.

Fig. 1. Douglas-fir beetle emergence by week of collection from 12 trees, each with a 1 X 2 foot cage, Cathedral Cliffs area, Wyoming, 1993.

(* symbol above date means collection not made that week)



For the '93-'94 DFB generation, overwintering brood density or mean brood production averaged 10.9 DFB per 36 square-inch sample or 43.7 per square foot of bark surface (Table 1). Brood density varied considerably both between sites and between trees within sites, despite the attempt to bias sample selection toward fully-occupied, heavily attacked trees (Table 1). One-third of the 30 samples summarized in Table 1 had some portion unoccupied by DFB due to pitch-out, the resin-exuding defensive reaction of Douglas-fir to attack by DFB. One-third of all samples had 5 or fewer DFB, although this set of samples only partially overlapped with the set of pitch-outs just mentioned. The only DFB-attacked tree found at the Dead Man Creek site had no brood, had been unsuccessfully attacked, and was not included in the data in Table 1.

There was no significant correlation between DBH and total brood per sample ($r_S = 0.09$, $p >> 0.05$, $n = 30$). Similar results were obtained when the association between DBH and total brood was assessed separately by north or south aspect.

New or callow adults, the typical overwintering stage of DFB brood, comprised only 21% of the life stages summarized in Table 1. Larvae were consistently present, accounting for 77% of the life stages in all samples, while only 2% of the DFB brood was in the pupal stage. No eggs were found. The percentage of DFB overwintering in immature stages was extremely high for the second consecutive year (Schaupp 1993).

For the years 1990-1993, there was no significant correlation between the percentage of immature brood and the average DFB brood per parent ($r_S = 0.35$, $p >> 0.05$, $n = 4$) or the ratio of current to previous generation average total brood density ($r_S = 0.65$, $p > 0.05$, $n = 4$). This means that the percentage of immature overwintering brood may not be directly associated with changes in brood population density.

Samples averaged 2.0 gallery starts per 36 sq. in. (8.1 per sq. ft.) with little variation (Table 1), indicating uniform attack densities among successfully colonized trees. About eight attacks per sq. ft. is within the average range observed by Lessard and Schmid (1990), also working during the fifth year of an epidemic in the Rocky Mountains. It is also on the high end of the range (4-8 attacks per sq. ft.) reported by McMullen and Atkins (1961) as being an indicator of maximum brood production. Assuming that one female and one male start each gallery, the density of gallery starts equates to 16.2 attacking DFB per square foot.

Mean total egg gallery length per bark sample varied by site ranging from 11-25 in. per 36 sq. in. (44 - 100 in. per sq. ft.) (Table 1). These gallery densities overlap the range of 30 - 60 in. per sq. ft. that reportedly represents maximum brood production levels (McMullen and Atkins 1961).

DFB natural enemies were rare at all sites (Table 1). Many samples had no enemies of DFB at all. Woodpecker activity on DFB-infested trees was noticed during field sampling.

Douglas-fir that successfully resisted DFB mass attack were consistently found at all areas examined. Though not quantified, a reduction in the number of successfully infested trees was noted as compared with 1992.

DISCUSSION

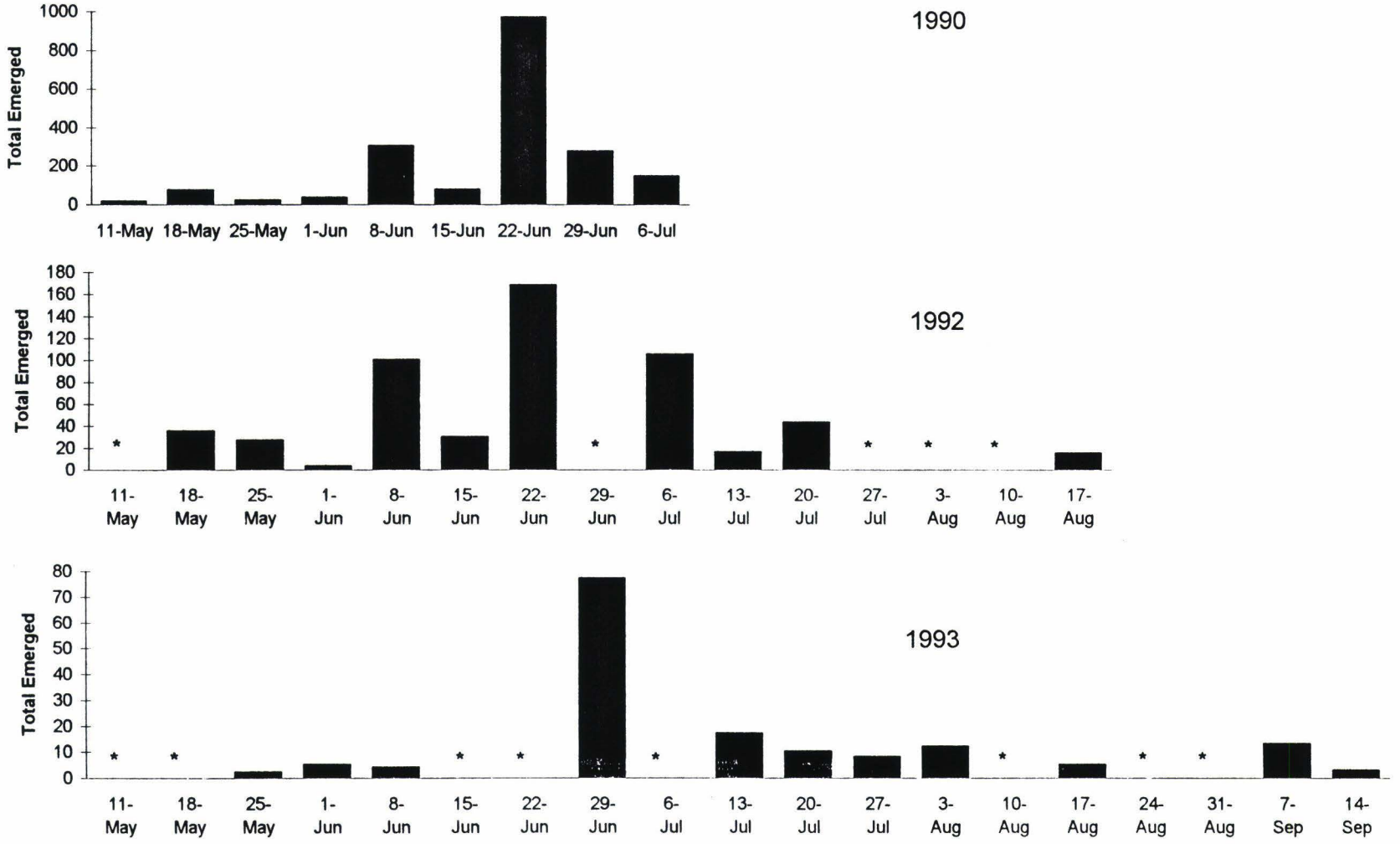
In 1992 and 1993, the caging period was lengthened by 6 and 10 weeks, respectively, beyond the caging period in 1990 (Pasek 1991; Schaupp 1993). Overall DFB emergence patterns were similar except for the detection of additional emergence in August and September (Fig. 2). It is possible that small numbers of DFB emerged before traps were installed. Wood (1982) states that DFB flight activity may begin as early as April, evidently continues at least until early September, and varies in its exact timing due to a variety of ecological factors.

During emergence trapping in 1990, 1992, and 1993, the majority of DFB adults was collected in June (Fig. 2; Pasek 1991; Schaupp 1993). The timing of this emergence peak matches more extensive results from northern Colorado (Lessard and Schmid 1990). While somewhat later than peak emergence reported from

Table 1. Douglas-fir beetle overwintering brood production, gallery characteristics and natural enemy numbers per 36 square inches of bark surface of two samples per successfully attacked tree taken at 5-7 feet height in the Cathedral Cliffs area of the Clarks Fork Ranger District, Shoshone National Forest, Wyoming, October 1993 (means ± standard deviation).

	Aspect	Cathedral Cliff Sale Area	Upper Reef Creek	Reef Creek Picnic Ground	All Sites
# Trees		8.0	5.0	2.0	15.0
DBH		20.5 ± 3.8	20.6 ± 2.6	21.3 ± 1.4	20.6 ± 3.1
Eggs	Both	0.0	0.0	0.0	0.0
Larvae	North	18.0 ± 5.9	2.8 ± 3.0		11.1 ± 8.9
	South	8.6 ± 9.3	1.6 ± 2.1		5.7 ± 7.5
	Both	13.3 ± 8.9	2.2 ± 2.5	4.3 ± 3.0	8.4 ± 8.6
Pupae	North	0.4 ± 0.7	0.4 ± 0.6		0.3 ± 0.6
	South	0.1 ± 0.4	0.0		0.1 ± 0.4
	Both	0.3 ± 0.6	0.2 ± 0.4	0.3 ± 0.5	0.2 ± 0.5
Adults	North	1.4 ± 1.9	0.8 ± 1.8		1.0 ± 1.7
	South	1.3 ± 2.8	7.2 ± 8.9		3.6 ± 5.9
	Both	1.3 ± 2.3	4.0 ± 6.9	2.0 ± 2.5	2.3 ± 4.5
Total Brood	North	19.8 ± 5.8	4.0 ± 3.8		12.5 ± 9.4
	South	10.0 ± 3.4	8.8 ± 9.2		9.4 ± 8.5
	Both	14.9 ± 9.2	6.4 ± 2.3	6.5 ± 3.9	10.9 ± 8.9
Gallery Starts	North	1.9 ± 0.8	1.6 ± 1.1		1.8 ± 0.9
	South	2.0 ± 1.3	2.2 ± 0.8		2.3 ± 1.2
	Both	1.9 ± 1.1	1.9 ± 1.0	2.8 ± 1.3	2.0 ± 1.1
Egg Gallery Length	North	24.0 ± 6.6	9.8 ± 3.3		17.9 ± 8.5
	South	25.0 ± 11.5	12.0 ± 4.3		20.0 ± 10.0
	Both	24.5 ± 9.0	10.9 ± 3.8	17.0 ± 4.3	19.0 ± 9.4
DFB Enemies: Beetles	North	0.1 ± 0.4	0.0		0.1 ± 0.3
	South	0.1 ± 0.4	0.0		0.1 ± 0.3
	Both	0.1 ± 0.3	0.0	0.0	0.1 ± 0.3
DFB Enemies: Wasps	North	0.4 ± 0.7	0.0		0.2 ± 0.6
	South	0.6 ± 0.9	0.0		0.5 ± 0.8
	Both	0.5 ± 0.8	0.0	0.5 ± 1.0	0.3 ± 0.7
DFB Enemies: Flies	North	0.3 ± 0.5	0.2 ± 0.5		0.2 ± 0.4
	South	1.0 ± 1.4	0.0		0.7 ± 1.8
	Both	0.6 ± 1.1	0.1 ± 0.3	0.5 ± 1.0	0.4 ± 0.9

Fig. 2. Total weekly emergence of Douglas-fir beetles during 1990, 1992 and 1993, Cathedral Cliffs area, Wyoming, from 1 X 2 foot cage sections on 12 or 8 (1992 only) trees. A * symbol above date means collection not made that week.



southern Idaho (Furniss 1962) and southern central British Columbia (McMullen and Atkins 1962), such variation may result from differing temperature patterns.

According to Wood (1982), two principal flight periods occur -- an early flight in May/June from brood that overwinter as new or callow adults and a later flight in July/August both from late-developing brood that overwinter as larvae and from parent adults reemerging from their first set of galleries. The concentrated emergence of new adults that would lead to an early flight is well-documented (Furniss 1962; McMullen and Atkins 1962; Lessard and Schmid 1990) and matches results summarized here (Fig. 2). However, the cited authors observed neither a later, second flight nor emergence of new adults sufficient to result in such a flight.

Emergence results reported herein suggest one peak of adult DFB emergence in May/June, with lesser numbers of beetles continuing to emerge into early September. For the two periods, May through June, and July until trap removal, emergence percentages were approximately 75% and 25% in 1992 and 56% and 44% in 1993, respectively (Fig. 2). The beetles that emerged during the later period may have resulted from late-developing brood that overwintered as immatures. Atypical weather conditions during early development and a high proportion of immature stages in overwintering brood can result in a less synchronous, prolonged and later flight period (McMullen and Atkins 1962). However, the late-emerging beetles in 1992 and 1993 were neither sufficiently numerous nor concentrated in time to produce a second peak of emergence. If a concentrated second flight does occur, it would have to consist primarily of reemerging adults (Lessard and Schmid 1990), which were not measured for this evaluation.

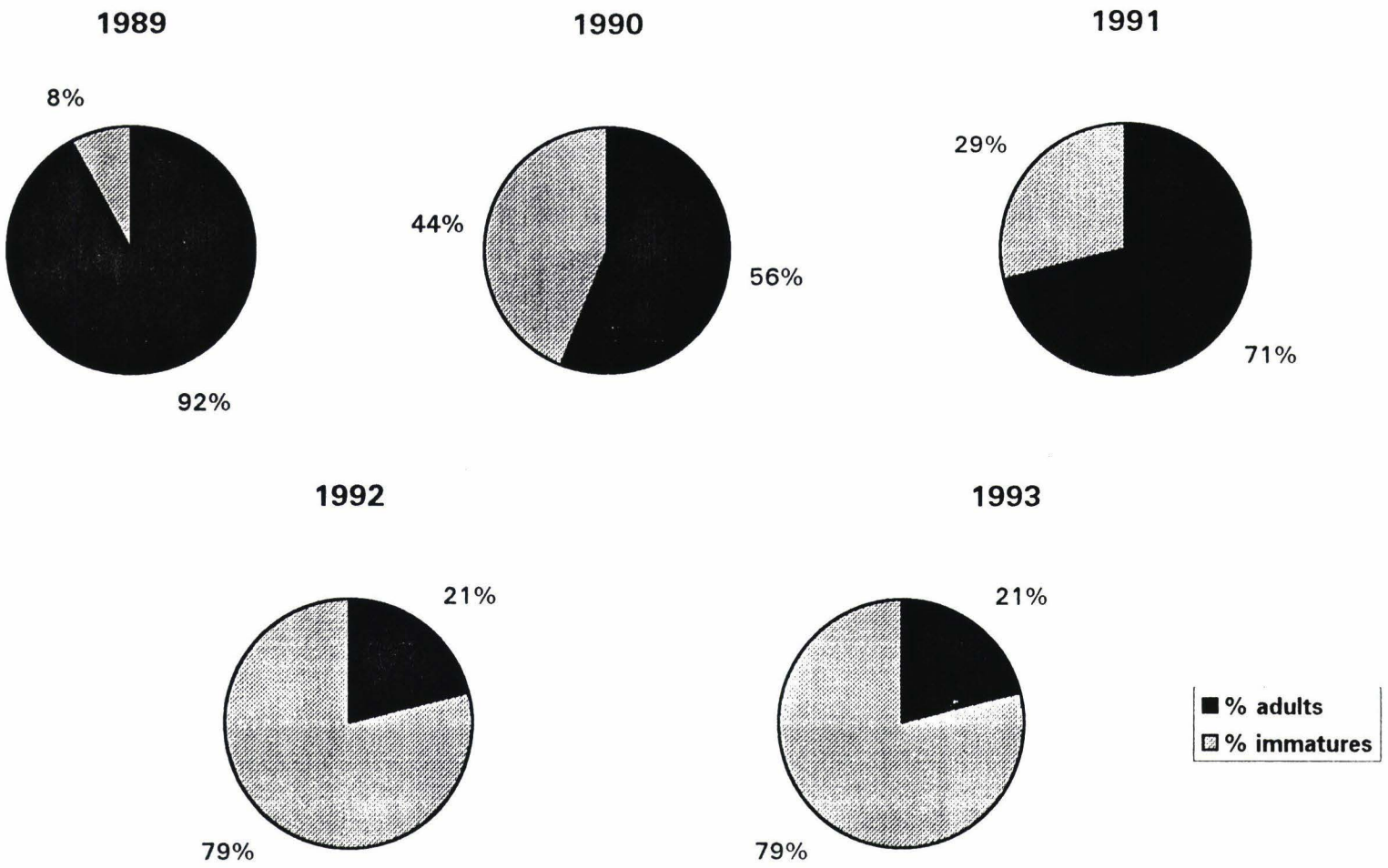
Because parent adult DFB can reemerge and attack additional trees, the attack period is not fully described by emergence results. It is likely that DFB actively search for host material throughout the summer. Reemergence is more rapid and common at higher attack densities (McMullen and Atkins 1962; Schmitz and Rudinsky 1968).

Population trend can be evaluated at the end of a generation by the ratio of beetles emerging from versus entering brood trees. This is calculated by dividing the density of emerging beetles by twice the density of gallery starts (attacks), assuming a pair of beetles initiates each attack. When the ratio of emergence to attack exceeds one, the population trend is increasing; when the ratio is less than one, the population trend is decreasing. For the '92-'93 DFB generation, the population trend was 0.36, coinciding with an overwintering brood in 1992 that was mostly immatures (Fig. 3).

Within a DFB generation, it may be that the percentage of brood that overwinter in immature stages is associated with the subsequent level of adult emergence. Adult emergence was only 5% of the estimated overwintering brood, which was 79% immatures, for the '92-'93 DFB generation. Adult emergence was 105% of the estimated overwintering brood, which was 29% immatures, for the '91-'92 DFB generation (Pasek and Schaupp 1992; Schaupp 1993). Adult emergence was 221% of the estimated overwintering brood, which was 8% immatures, for the '89-'90 DFB generation (Pasek 1990; Pasek 1991). Because of low sample sizes (observations made on 8-16 trees per year), this trend should be interpreted cautiously. The level of emergence is affected by overwintering brood mortality from adverse weather, mortality from intraspecific competition and natural enemies, and DFB that survive, yet fail to emerge, as in 1993.

High mortality among predominantly immature overwintering broods has been considered to contribute to the decline of epidemic DFB populations. Chansler (1968) found that a high proportion of larvae remaining among broods in the spring preceded a downward trend in a New Mexico infestation in two consecutive years. Furniss (1965) concluded that a long-term infestation in southern Utah subsided because of slow brood development, characterized by brood overwintering as immatures. McMullen (1970) also documented an extended life-cycle in DFB populations that overwintered as immatures and showed that adults from such extended populations produced as many or more broods than normal populations. He concurred with Furniss (1965) that extension of the life cycle to 2 years would tend to reduce populations through mortality occurring within trees.

Fig. 3. Percentages of overwintering adult and immature Douglas-fir beetles from late fall samples of bark taken at 5-7 foot height from successfully attacked trees in the Cathedral Cliffs area, Clarks Fork Ranger District, Shoshone National Forest, Wyoming, for 5 years following the Clover Mist fire of 1988.



It is highly likely that part of the DFB population in northwestern Wyoming is undergoing a shift to a 2-year life cycle. This assertion is supported by the finding, for the '92-'93 DFB generation, of live DFB adults under the bark of brood trees 1 1/2 years following attack and by documentation of high percentages of immature beetles in the overwintering populations from which these adults developed (Schaupp 1993). Such a shift is thought to result from delays in establishment and/or development of brood due to weather effects. This life cycle extension may continue for the '93-'94 DFB generation due to the impact of the cool temperatures in the summer of 1993, resulting in another predominantly immature overwintering brood (Fig. 3). We suspect that this shift will lead to increased DFB brood mortality.

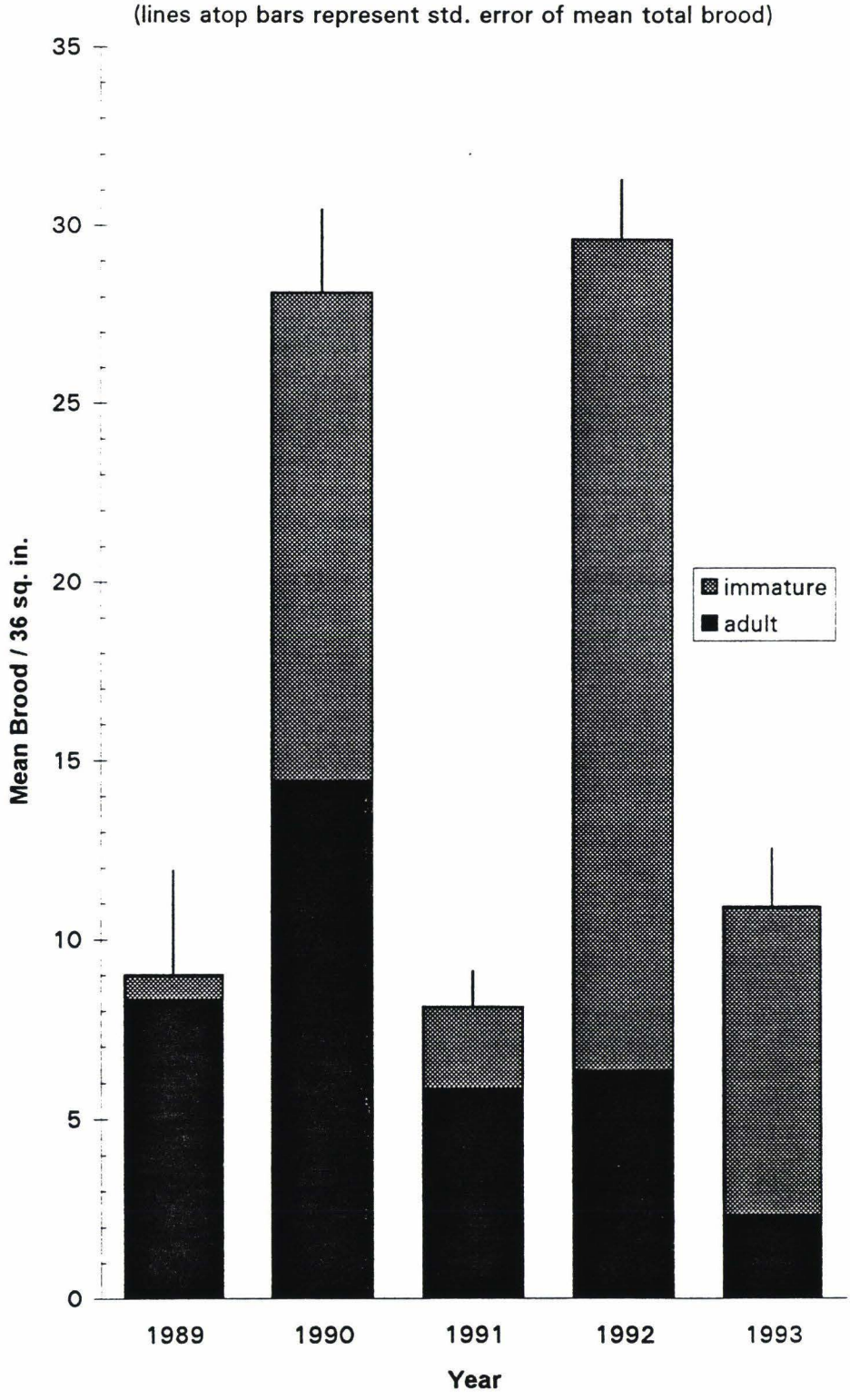
Another factor difficult to account for is DFB mortality due to its insect natural enemies. After building from relatively low levels in 1990 when the DFB epidemic began (Pasek 1991), insect natural enemies of DFB brood remained at increased levels for 2 years due to the continuing presence of large numbers of DFB. However, for 1993 brood, it appears that insect natural enemies of DFB have declined to or below the 1990 levels, although reliable quantitative estimates require far more time and effort than could be expended (Marsden et al. 1981).

Although not quantified, it was obvious during field work in fall 1993, that trees across a wide diameter range had resisted DFB attack. The largest such tree observed measured 40" DBH. It was difficult to locate successfully attacked trees to sample for DFB brood production. None suitable for brood sampling were found at the Camp Creek and K-Z Ranch sites, despite careful examination of all potentially suitable trees on at least 10 acres at each site. At the K-Z Ranch site, most Douglas-fir greater than about 15" DBH had already been killed. All attacked trees in the 9-15" DBH range had successfully resisted DFB brood establishment. While it is possible that rating trees from the ground for failure of DFB attack results in an overestimate (Furniss et al. 1979), it is clear that the level of resistance in the Douglas-fir population was high in 1993. The abundant summer rain, a smaller DFB population, and the depletion of suitable hosts all may have played a role in this observed resistance. The increase in trees that effectively pitched out DFB may indicate that the most suitable host trees have already been killed and that the vigor of remaining trees was increased by favorable weather conditions in 1993. If the latter was the case, a return to more typical weather in 1994 and later years could again increase susceptibility of potential host trees to attack by DFB. Brood density can readily increase from one year to the next as happened in 1990 and 1992 (Fig. 4).

Overwintering brood densities in fall 1993 samples dropped back to a level similar to those found in 1989 and 1991 (Fig. 4). Attack densities remained high at 8.1 gallery starts per sq. ft., indicating effective mass attack of host trees. Lessard and Schmid (1990) found that such attack densities in trees > 10" DBH generally are indicative of increasing population levels. However, many of the samples had unoccupied areas indicating that brood establishment may have been less than optimum. The cool, wet summer of 1993 likely contributed to greater resin flow that was able to resist DFB in some portions of the attacked trees. Areas that were successfully attacked produced brood densities indicative of healthy and increasing population levels. The number of DFB brood per attacking adult, calculated as the average density of total brood divided by twice the average density of gallery starts, can be used as an index of population change. For 1994, this population index foretells an increase ranging from 1.2 to 3.8 times by site, with an overall weighted average of 2.8 times.

The DFB population is therefore likely to be larger in 1994 than it was in 1993. Beetles from the '92-'93 DFB generation that successfully complete a 2-year life cycle will emerge in 1994 and add to the anticipated population increase. Before the overwintering DFB mature and emerge to attack other trees in the summer of 1994, biotic and especially abiotic mortality factors will reduce the size of the beetle population. The magnitude of these mortality effects is unpredictable. As a result, fall brood sampling, as reported here, tends to overestimate the magnitude of population changes. For example, unseasonably cold temperatures could result in high DFB brood mortality causing a smaller than expected increase or even a decrease in adult DFB population levels in 1994. In the case of high DFB overwintering survival, our information predicts a 2-3 fold increase in the adult DFB population for 1994.

Fig. 4. Douglas-fir beetle, overwintering brood by year, Cathedral Cliffs area, Wyoming



Such a population increase should be reflected in greater numbers of trees being attacked in 1994 relative to 1993, given that attack densities have remained relatively constant throughout the course of the current epidemic. An exception to this general condition will occur in stands depleted of suitable hosts due to several years of DFB infestation; in these places, DFB attacks should decline.

The level of host resistance to DFB attack, together with the size of the adult DFB population, will dictate if these attacks will lead to an increase in Douglas-fir mortality. The increased host resistance witnessed in 1993 may be a temporary condition, or it may be an indication of the beginning of a downward trend for the epidemic. An increase in host resistance may play a role in ending DFB epidemics (Furniss et al. 1979). The number of Douglas-fir trees that will be killed by DFB in 1994 on the Clarks Fork Ranger District cannot be accurately predicted. Our evidence indicates that, barring unusual conditions, the DFB epidemic will continue.

ALTERNATIVES

Several methods are available to reduce populations of DFB and the resultant tree mortality. These pest management strategies may focus on the reduction of infested material, reduction of susceptible host material, or prevention of new attacks. The decision to use a particular method should be predicated on considerations of stand conditions, location, management objectives, economics, social values, and other factors.

Alternative 1:

Sanitation Harvesting - Fell infested trees and remove them from the site for mill processing prior to adult DFB emergence. Stands with the highest percentages of large-diameter Douglas-fir should be given priority.

Where to use - Sites with the following conditions are appropriate: accessible to logging operations such as near existing roads or where roads can be readily constructed; less than 40% slope; where human disturbance will not adversely affect special resource values; and in proximity to high value areas that need to be protected.

Advantages - Beetle broods can effectively be eliminated in small, isolated loci by removing all infested trees prior to beetle emergence. Beetle populations in larger groups can be significantly reduced. Sanitation harvesting provides a degree of protection to surrounding, uninfested trees by removing a nearby source of attacking beetles, recovers timber volume that otherwise would be lost, reduces fuel load, reduces subsequent hazard from falling trees and inaccessibility to large animals, reduces visual impact of dead and dying trees, and will encourage regeneration and greater diversity of size and age classes across the forest.

Disadvantages - Short implementation time is required; trees must be removed prior to adult emergence in the spring following attack. Adverse disturbance of the site and soil is possible. Sanitation harvesting may remove tree cover in spots or at a density considered adverse aesthetically.

Alternative 2:

Tree Baits - Commercially available DFB tree baits containing attractant semiochemicals (aggregation pheromone) can be used to concentrate beetles in trees that can be subsequently harvested. Baits are deployed just prior to beetle flight (May) and baited trees must be felled and removed or destroyed prior to the next adult emergence period (i.e., within 1 year).

Where to use - Ideal sites for placement of baits would be Douglas-fir trees in and around salvage operations. Baited areas must be suitable for harvest (Alternative 1) or mechanical control (Alternative 3). Baiting is likely to be most effective in areas where beetle populations are small; e.g., it is useful as a mop-up operation following removal of infested trees. Baiting is not suitable for large population centers; the native beetle population quickly overwhelms the baits in this situation.

Advantages - Baiting may provide some degree of redirection of beetle attacks to trees where salvage can be implemented. Beetles emerging from infested trees that were missed during salvage harvesting in 1 year may be concentrated in logs or trees for removal the following year.

Disadvantages - Application is generally limited to sites accessible to harvest and where beetle populations are low and relatively isolated from larger population centers.

Alternative 3:

Mechanical Control - Fell and buck infested Douglas-fir trees and treat them by burning, peeling the bark, or chipping the logs.

Where to use - Use in unroaded areas or on steep slopes that are accessible on foot (or horseback) to logging but where road building or skidding is undesirable. Sites where no logging company is interested in bidding on the timber or volume is too small to put up a sale also are appropriate.

Advantages - Much of the beetle brood can be eliminated from small pockets even in the absence of a timber market. Mechanical control provides a degree of protection to surrounding, uninfested trees by removing a nearby source of attacking beetles. It also reduces subsequent hazard from falling trees and inaccessibility to large animals, reduces visual impact of dead and dying trees, and will encourage regeneration and greater diversity of size and age classes across the forest. Potential for site and soil disturbance is less than for Alternative 1.

Disadvantages - Mechanical control is labor intensive, does not recover value and volume from trees, leaves a high fuel load on the site, removes tree cover, and requires a short implementation time; trees must be treated prior to adult emergence in the spring following attack. It is not effective where large populations are present in adjacent areas.

Alternative 4:

Trap Trees - Green trees can be felled and left on the site to attract beetles. Felled logs are sprayed with carbaryl in April or May, just prior to the beetle attack period, so that beetles will be killed as they enter the logs. Tree baits can be used on felled logs to increase their attractiveness to beetle attack.

Where to use - Use in small infestation pockets where salvaging, mechanical control, or reentry is impractical. Also use in unroaded areas or on steep slopes that are accessible on foot (or horseback) to logging but where road building or skidding is undesirable. Sites where no logging company is interested in bidding on the timber or volume is too small to put up a sale also are appropriate. Trap trees may be used as a tool to mop-up a population following salvaging.

Advantages - Use of trap trees concentrates beetle attack away from trees where protection is desired, kills beetles, does not require sale preparation and administration, can be used on sites with steep slopes or where roads do not exist and are not desirable, and is not as labor intensive as mechanical control.

Disadvantages - Use of trap trees does not recover value and volume from trees, leaves a high fuel load on the site, and removes tree cover.

Alternative 5:

Silvicultural Treatment - To reduce susceptibility in green stands, basal area should be reduced below 80% of normal stocking (Furniss et al. 1981). Mature and old stands of Douglas-fir can be harvested. Younger stands should be thinned periodically to improve vigor and reduce moisture stress.

Where to use - This is a preventative treatment that should be considered as an ongoing part of the regular timber program. Due to limited staffing and funding, this alternative may not be feasible during an epidemic where resources are better spent on other options.

Advantages - Silvicultural treatment reduces susceptibility of stands to beetle attack, which may limit tree mortality and infestation size in the event of a future increase in beetle population.

Disadvantages - This alternative is not suitable for sites where harvesting activity is not desirable, such as in Wilderness, on steep slopes, or where visual quality would be adversely impacted.

Alternative 6:

Protection of High Value Trees - Prior to beetle flight in early spring (April or May), the boles of valuable trees can be sprayed with carbaryl to prevent DFB attack.

Where to use - This method would be appropriate for use in and around campgrounds and private homes. Trees must be of high value. Insecticide application is not effective for trees that have already been infested.

Advantages - Insecticide application provides a degree of protection not currently available through other mitigation strategies. Carbaryl has a low mammalian toxicity and low residual activity, which means it remains in the environment for a short period of time.

Disadvantages - Efficacy for protection of Douglas-fir needs to be demonstrated by a test prior to operational usage. Material is toxic to other insects as well as to DFB. Many citizens have concerns about environmental contamination and safety. Insecticide application does not effectively reduce the existing beetle population, is expensive if very many trees are treated, and size of treatment areas need to be small due to cost and labor considerations.

Alternative 7:

Repellents - A granular controlled-release formulation of the DFB anti-aggregative pheromone, 3-methyl-2-cyclohexen-1-one (MCH), can be broadcast or aerially applied to stands where protection is desired. This alternative currently requires an experimental use permit, because registration of the material with EPA is not yet completed.

Where to use - The method is most suited for high value and inaccessible stands that are not currently infested but are threatened by nearby beetle populations.

Advantages - MCH is non-toxic; it is a natural chemical that is produced by DFB. Use of MCH is a promising method of preventing new attacks.

Disadvantages - MCH does not directly reduce the existing beetle population. Granular application distributes plastic pellets into the environment. Availability of the material may be a problem. MCH is not yet registered.

Alternative 8:

Do Nothing - Accept tree mortality caused by DFB as a natural phenomenon.

Where to use - Use where other control alternatives cannot be effected or are not desired. This may be the only viable alternative for infested stands that are inaccessible, areas designated as Wilderness, and sites where the visual and erosive impacts of harvesting are a major concern.

Advantages - No unnatural site disturbance or introduction of foreign materials into the environment will occur. Change in vegetation follows a natural event.

Disadvantages - The no-action alternative allows the beetle population to continue to increase and threaten additional sites. Tree volume and value is lost, visual quality is adversely affected by dying and dead trees, fuel load increases, tree hazard increases, inaccessibility to large animals increases with time as trees fall over, and tree regeneration is inhibited due to shading by remaining dead trees and lack of seedbed preparation.

RECOMMENDATION

Emphasis should be placed on long-range management planning to increase the health of forest stands and reduce susceptibility to DFB attack (Alternative 5). This is particularly appropriate for stands in the suitable timber base where emphasis is placed on timber production and for areas where loss of tree cover is undesirable. Priority for silvicultural treatment should be given to older, dense stands of predominantly Douglas-fir composed of large diameter (> 16" DBH) trees. Within a couple years, Forest Health Management staff expect to develop a stand risk/hazard rating system for DFB that can serve as an aid to prioritizing stand treatments and assessing effects of various management alternatives.

Removal of currently-infested trees (Alternative 1) should be incorporated into any harvesting or thinning operations to further reduce DFB populations in the immediate vicinity. This alternative is appropriate for stands being managed to improve long-term sustainability (Alternative 5) and for stands where tree losses are imminent and a reduction in DFB impact is currently desirable.

Alternative 4 may be appropriate where baits can be used to lure residual DFB populations to log decks for subsequent removal. Successive baiting and sanitation harvesting may be needed using this method.

DFB populations likely are still too high for Alternative 2 to be effective. The natural pheromone of the beetles may overwhelm artificial baits attached to standing, green trees such that infestation spreads beyond the intended area. This alternative is not recommended at present.

Alternatives 3 and 6 may be useful for treating or protecting high value sites, such as campgrounds or homesites.

Alternative 8 may be selected of necessity in much of the Clarks Fork Ranger District because of extensive areas of Wilderness affected by the Clover Mist Fire, concerns for the protection of certain wildlife species, the presence of inaccessible areas, the concern for visual and erosive impacts of harvesting options, and the constraints on time and personnel available to treat infested sites.

Land managers need to develop site-specific plans to manage stands relative to anticipated effects of DFB in relation to desired conditions and resource objectives stated in a Forest Plan. Alternatives should be weighed in relation to site-specific characteristics.

Forest Health Management personnel will continue to assist in reassessing DFB populations and DFB-caused tree mortality as needed during the course of the infestation.

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